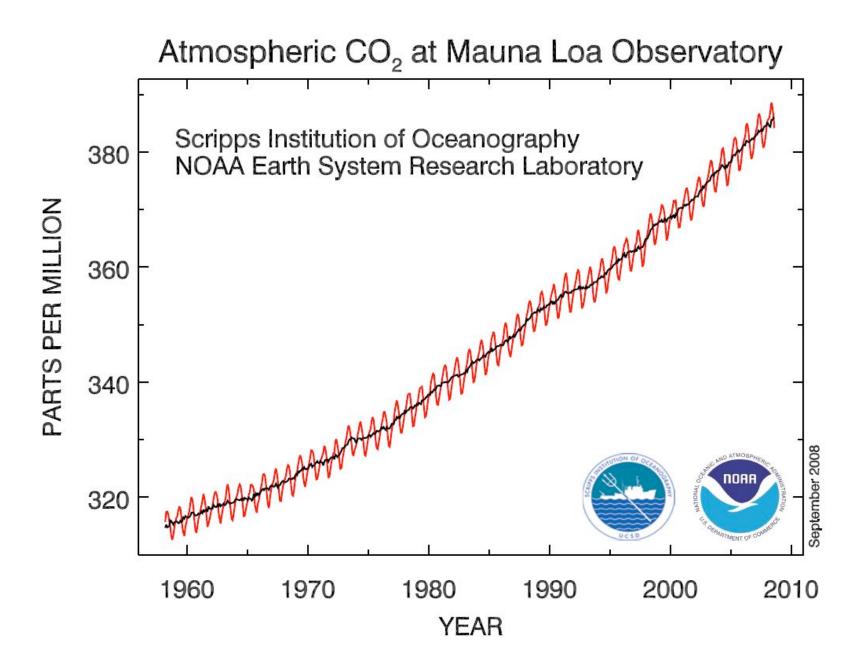
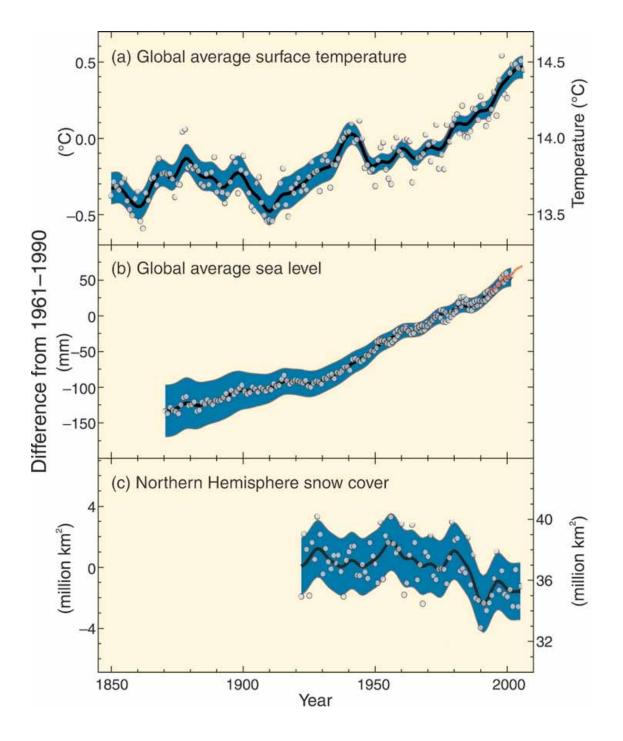


Presentation Overview

- 1. Ocean acidification overview what is it, and where are we headed?
- 2. Site specific findings: Effects on CINMS (and other West Coast sanctuaries)
- 3. CINMS Advisory Council process to investigate this issue
- 4. CINMS Advisory Council recommendations for our Superintendent
- 5. Epilogue What's happened since





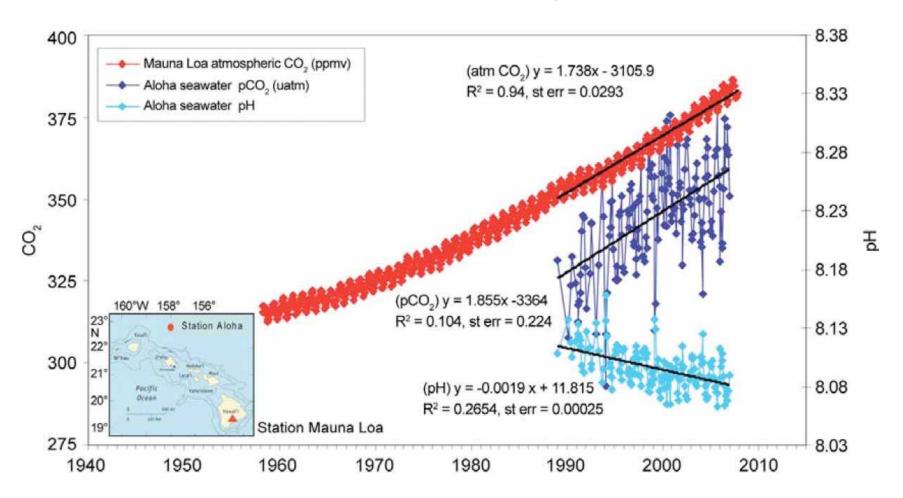
Observed changes in

- global average surface temperature,
- global average sea level, and
- northern hemisphere snow cover for March-April.

All differences are relative to corresponding averages for the period 1961- 1990.

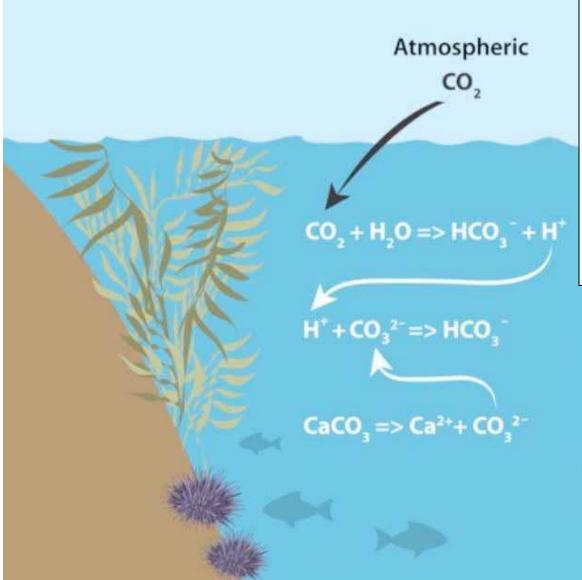
Source: IPCC AR4, 2007 (http://www.ipcc.ch)

Atmospheric CO_2 at Mauna Loa (ppmv) and surface ocean pH and pCO_2 (carbon dioxide concentration) in the subtropical North Pacific Ocean (Feely 2008)



Mauna Loa data: Dr. Pieter Tans, NOAA/ESRL, www.esrl.noaa.gov/gmd/ccgg/trends; HOTS/Aloha data: Dr.David Karl, University of Hawaii, http://hahana.soest.hawaii.edu. **Graph excerpted from: Feely, R.A. 2008**. "Ocean Acidification." In: State of the Climate in 2007. Available at: http://www.ncdc.noaa.gov/oa/climate/research/2007/ann/bams/

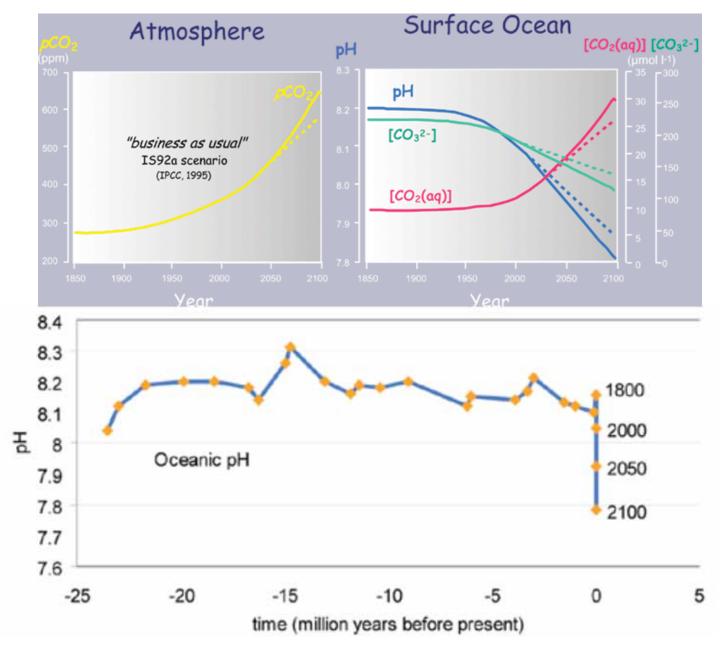
Ocean Acidification 101



- Increased emissions forces CO₂
 dissolution into the oceans
- Increased CO₂ concentration in seawater leads to higher H⁺ concentration, consumption of carbonate, and production of bicarbonate (HCO₃⁻)
- Dissolution of calcium carbonate (CaCO₃).

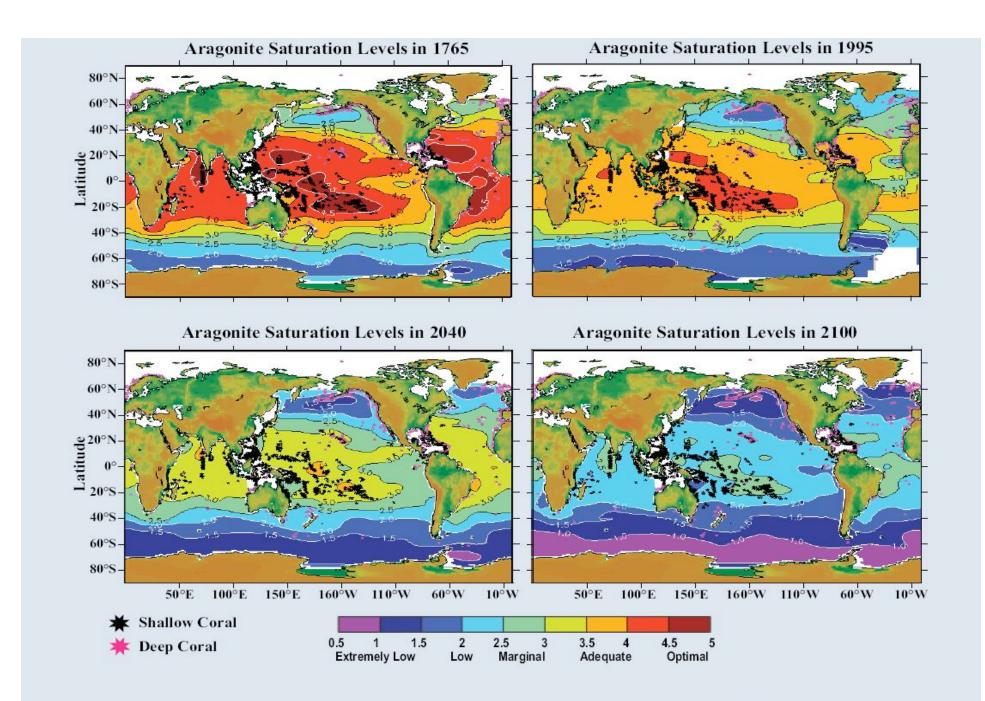
	1XCO ₂	2XCO ₂	3XCO ₂
[CO ₂]	280	560	840
[CO ₃ ²⁻]	268	176	115
рН	8.15	7.91	7.76

(slide adapted from G. Hofmann; data: Kleypas et al 2006)



Top: adaptation of Wolf-Gladrow et al. 1999 "Direct effects of CO₂ concentration on growth and isotopic composition of marine plankon." Tellus B, 51, 461-476, by The Ocean Acidification Network http://www.ocean-acidification.net

Bottom: excerpted from Plymouth Marine Lab fact sheet. May 2007, and based on from Turley et al, 2006. Cambridge University Press, 8, 65-70).



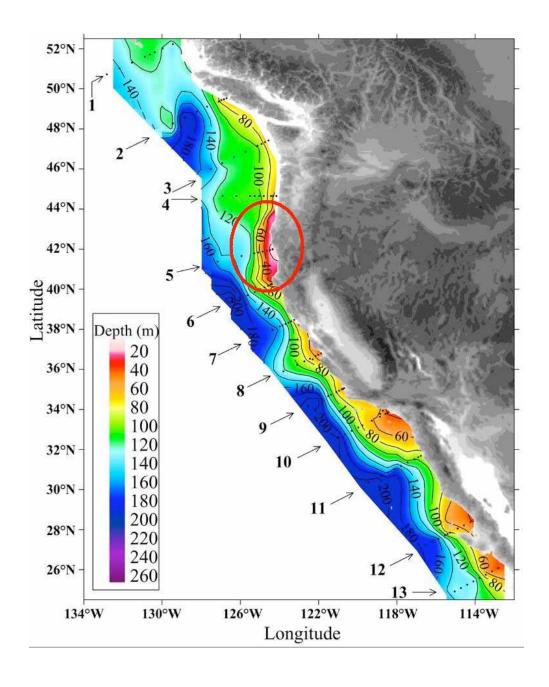
Estimated aragonite saturation states of the surface ocean for the years 1765, 1995, 2040, and 2100 (Feely et al., submitted), based on the modeling results of Orr et al. (2005) and a Business-As-Usual CO_2 emissions scenario. The distributions of deep-sea coral banks are from Guinotte et al. (2006).

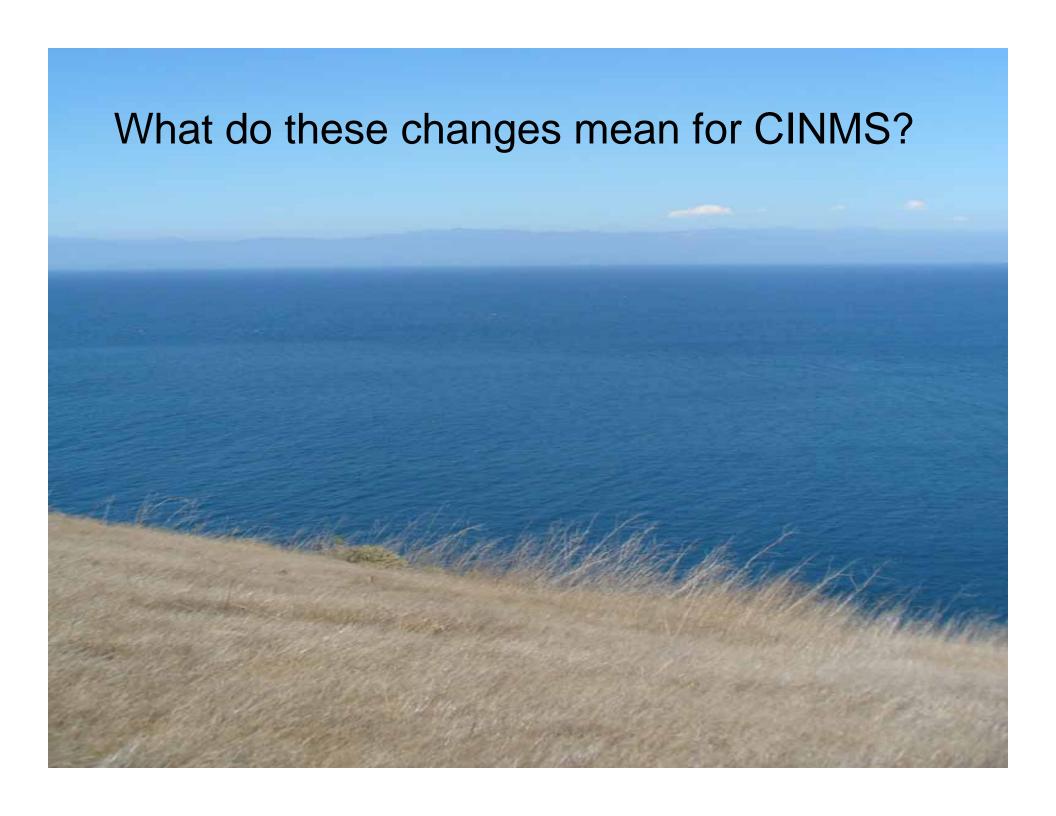
Feely et al., 2008: "Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf"

"Distribution of the depths of corrosive water (aragonite saturation <1.0; pH <7.75) on the continental shelf of Western North America."

Data from 2007 trawl.

Red circle indicates area of shoaling (surfacing) of corrosive seawater within the nearshore coastal environment off Northern California.





Responses of marine fauna to ocean acidification (a few examples)

Excerpted from:

Fabry et al. 2008

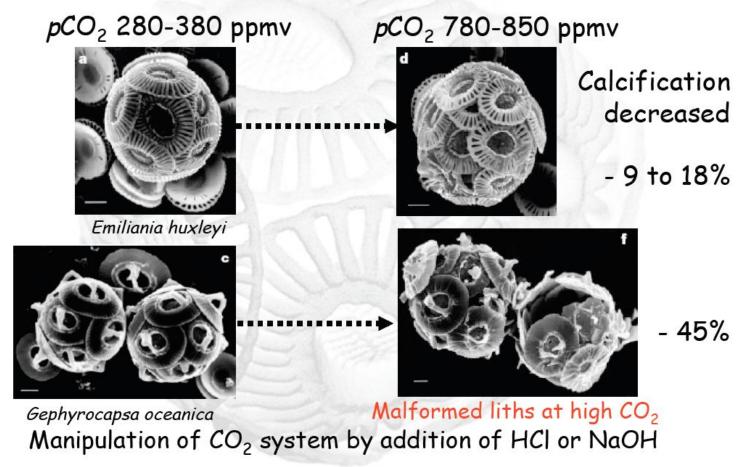
"Impacts of ocean acidification on marine fauna and ecosystem processes"

ICES Journal of Marine Science, 65: 413-32.

Species	Description	CO ₂ system parameters	Sensitivity	Reference
Planktonic foraminifera				
Orbulina universa	Symbiont-bearing	pCO ₂ 560 – 780 ppmv	8-14% reduction in shell mass	Spero et al. (1997); Bijma et al. (1999, 2002)
Globigerinoides acculfer	Symbiont-bearing	pCO ₂ 560 - 780 ppmv	4-8% reduction in shell mass	Bijma et al. (1999, 2002)
Cnidaria				
Scyphozoa Hydrozoa	Jellyfish	North Sea seawater pH drop from 8.3 to 8.1	Increase in frequency as measured by CPR from 1958 to 2000	Attrill et al. (2007)
Mollusca				
Clio pyramidata	Shelled pteropod	$\Omega_{arag} < 1$	Shell dissolution	Feely et al. (2004); Orr et al. (2005); this work
Haliotis laevigata	Greenlip abalone	pH 7.78; pH 7.39	5% and 50% growth reductions	Harris et al. (1999).
Haliotis rubra	Blacklip abalone	pH 7.93; pH 7.37	5% and 50% growth reductions	
Mytilus edulis	Mussel	pH 7.1 / 10 000 ppmv	Shell dissolution	Lindinger et al. (1984)
		pCO ₂ 740 ppmv	25% decrease in calcification rate	Gazeau et al. (2007)
Crassostrea gigas	Oyster	pCO ₂ 740 ppmv	10% decrease in calcification rate	
Mytilus galloprovincialis	Mediterranean mussel	pH 7.3, ~5000 ppmv	Reduced metabolism, growth rate	Michaelidis et al. (2005)
Placopecten magellanicus	Giant scallop	pH < 8.0	Decrease in fertilization and embryo development	Desrosiers et al. (1996)
l'ivela stultorum	Pismo clam	pH < 8.5	Decrease in fertilization rates	Alvarado-Alvarez et al. (1996)
Pinctada fucada	Japanese pearl	pH 7.7	Shell dissolution, reduced growth	Reviewed in Knutzen (1981)
nartensii	oyster	pH ≥7.4	Increasing mortality	
Mercenaria mercenaria	Clam	$\Omega_{arag} = 0.3$	Juvenile shell dissolution leading to increased mortality	Green et al. (2004)
llex illecebrosus	Epipelagic squid	2000 ppmv	Impaired oxygen transport	Pörtner and Reipschläger (1996)
Dosidicus gigas	Epipelagic squid	0.1% CO ₂ , ~1000 ppmv	Reduced metabolism/scope for activity	Rosa and Seibel (unpublished)
Arthropoda		pp		
Acartia steueri	Copepod	0.2-1%CO ₂ ,	Decrease in egg hatching success:	Kurihara et al. (2004)
Acartia erythraea	Copepod	~2000 - 10 000 ppmv	increase in nauplius mortality rate	reminara et te. (2004)
Copepods	Pacific, deep vs. shallow	860 – 22 000 ppmv CO ₂	Increasing mortality with increasing CO ₂ concentration and duration of	Watanabe et al. (2006)
			exposure	
Euphausia pacifica Paraeuchaeta elongata	Krill Mesopelagic	pH < 7.6	Mortality increased with increasing exposure time and decreasing pH	Yamada and Ikeda (1999)
Conchoecia sp.	Copepod Ostracod			
Cancer pagurus	Crab	1% CO₂, ~10 000 ppmv	Reduced thermal tolerance, aerobic scope	Metzger et al. (2007)
Chaetognatha				
Sagitta elegans	Chaetognath	pH < 7.6	Mortality increased with increasing exposure time and decreasing pH	Yamada and Ikeda (1999)
Echinodermata				
Strongylocentrotus	Sea urchin	pH ~62-73	High sensitivity inferred from lack	cf. Burnett et al. (2002)
purpuratus		P. 1 - O.K. 7 13	of pH regulation and passive	- Samer et an fenne)
Psammechinus miliaris	Sea urchin		buffering via test dissolution during emersion	Spicer (1995); Miles et al. (2007)
Hemicentrotus	Sea urchin	~500 – 10 000 ppmv	Decreased fertilization rates,	Kurihara and Shirayama (2004)
oulcherrimus Ichinometra mathaei	Sea urchin		impacts larval development	
Echinometra mathaei Cystechinus sp.	Deep-sea urchin	pH 7.8	80% mortality under simulated CO ₂ sequestration	Barry et al. (2002)







Riebesell et al.(2000); Zondervan et al.(2001)

Slide credit: Richard Feely NOAA PMEL



"Although the changes in seawater chemistry that result from the oceanic uptake of anthropogenic CO2 are well characterized over most of the ocean, the biological impacts of ocean acidification on marine fauna are only beginning to be understood.

Nevertheless, sufficient information exists to state with certainty that deleterious impacts on some marine species are unavoidable, and that substantial alteration of marine ecosystems is likely over the next century....

We conclude that ocean acidification and the synergistic impacts of other anthropogenic stressors provide great potential for widespread changes to marine ecosystems."

Fabry et al. (2008).

Sanctuary Advisory Council Process

2007:

- Commercial fishing member (Bruce Steele) raises concerns
- Conservation Working Group begins initial literature research, outreach to experts.

2008:

- Assistance by the Commercial Fishing Working Group
- Draft report development by Conservation Working Group
- Technical reviews by SAC Research Activities Panel and other outside experts
- Presentations to Sanctuary Advisory Council by experts:
 - > Dr. Victoria Fabry, CSU San Marcos
 - > Dr. Gretchen Hofmann, UC Santa Barbara
 - Dr. Richard Feely, NOAA Pacific Marine Environment Lab
- Unanimous vote of Sanctuary Advisory Council to endorse report and recommendations (Sep 2008)





- Significant changes in Sanctuary ocean chemistry within decades or shorter
- Adverse effects to ecologically important Sanctuary species
- Long term conservation of Sanctuary resources requires immediate action



1. Research

NOAA/CINMS should:



- Prioritize the organization of a baseline of physical and biological data relevant to understanding the local effects of ocean acidification
- Systematically identify data gaps and research needs
- Build partnerships with researchers and institutions that can illuminate those effects and fulfill those needs

2. Monitor

Track changes in acidification-related physical and

biological indicators over time

 Learn how the Sanctuary's acidification/CO₂ sensitive species and their ecosystems are affected by these changes



3. Educate

Use existing education and outreach programs to increase awareness of ocean acidification among Sanctuary stakeholders and the public.



Include causes of ocean acidification, effects on Sanctuary resources and ecosystems, and actions that can reduce individual and collective exacerbation of ocean acidification.

- a. Leverage existing programs (e.g. MERITO [Multicultural Education for Resource Issues Threatening Oceans], CI Naturalist Corps, and Advisory Council).
- b. Incorporate Sanctuary-specific ocean acidification information from current and future research and monitoring.

4. Lead

Seize the opportunity to address ocean acidification through leadership among stakeholders and public, and ONMS and NOAA.



Focus on:

- a.CO₂ emissions reductionin Sanctuary operations & uses
- b. Management planning,coordination & action, at local, regional, and national levels.

Epilogue

West Coast sanctuary advisory councils in 2008/9:

- GFNMS Advisory Council adopts the Channel Islands report and recommendations (Dec. 2008)
- Joint resolution adopted by MBNMS & GFNMS advisory councils asking for regional coordination of research, monitoring and management actions (Feb 2009)
- OCNMS Advisory Council adopts resolution (matching GFNMS/MBNMS resolution) (March 2009)
- CBNMS Advisory Council adopts resolution (matching Joint MBNMS/GFNMS advisory councils (April 2009)
- MBNMS Advisory Council to consider Channel Islands report and recommendations (June 2009)

Epilogue, continued...

- Support from NOAA's Pacific Marine Environment Lab:
 - Strong support for coordinated ocean acidification research in National Marine Sanctuaries

"The Channel Islands National Marine Sanctuary Report on Ocean Acidification is a comprehensive action plan that I hope will be emulated by the other members the National Marine Sanctuary Program."

-Dr. Richard Feely, NOAA Pacific Marine Environmental Laboratory, Seattle, Washington. December 3, 2008

- Federal Ocean Acidification Research and Monitoring (FOARAM) Act
 - -Enacted by Congress (March 25, 2009) and signed by President Obama. New funds authorized for NOAA and NSF but not yet appropriated.

Thank you.

"Ocean Acidification and the Channel Islands National Marine Sanctuary: Cause, effect, and response"

Available at:

www.Channellslands.noaa.gov

(>> "Advisory Council"

>> "Reports & Documents")

Or contact
Shiva Polefka shiva@edcnet.org

Ocean Acidification and the Channel Islands National Marine Sanctuary: Cause, effect, and response



Red abations, wichors, and corolline algae - familiar valisfiers of the Northern Channel Islands - Photo: CISMS

A report by the Conservation Working Group of the CINMS Advisory Council

Adopted by the CINMS Advisory Council September 19, 2008

Prepared by:

Shiva Poletka, Marine Conservation Analyst, and Julia Forgie, Program Intern, Environmental Defense Center, Santa Barbara, California (contact: shiva@edenet.org)

Project director

Linda Krop, CINMS Advisory Council Conservation Seat and Chief Counsel, Environmental Defense Center

Supported by the Marisla Foundation